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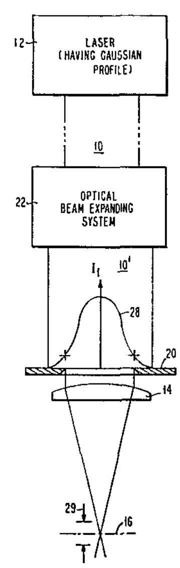
(54) Focussed laser beam optical system.

(57) The focal range of a focussed laser beam optical system is enlarged where the beam has a guassian cross-sectional profile. A stop 20 is arranged, after a beam expanding system 22, between the laser 12 producing the beam 10, and a beam focussing lens system 14. The stop is provided with an aperture of predetermiend diameter with respect to that of the laser beam 10 whereby the outer portion of the expanded beam 10' represented by the low intensity skirts of the intensity profile curve 28 is stopped. This arrangement can influence the focal range up to a 75 per cent increase over that obtained with the unexpanded and unstopped beam.



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FOCUSSED LASER BEAM OPTICAL SYSTEM

The invention relates to optical systems for focussing laser beams on a given target.

Focussed laser beams are used extensively. One important application is that of the point-of-sale recording system wherein coded labels are scanned with a focussed laser beam. A problem is experienced in this application in that a reasonably sized focussed spot is required while there is always considerable uncertainty as to the distance between the focussing lens and the surface over which scanning takes place. Another important application is found in a high-speed, high-resolution laser printing system where a similar problem arises.

Past attempts to solve this problem have resorted to refinements of old optical systems that are expensive, bulky and difficult in manufacture and/or adjustment in the field. It is an object of the present invention to provide a focussed laser beam optical system having a reasonably sized, focussed light spot which has an acceptable range or depth of focus.

This object is attained in an optical system comprising a device generating a laser beam having a gaussian characteristic cross-sectional profile and a beam focussing device by the interposition of an optical stop in the laser beam between the devices. More particularly, the stop is arranged with an aperture stopping the beam intermediate the skirt of the characteristic profile thereby to extend the focal range of the beam at the target. Preferably, the aperture is dimensioned to truncate the laser beam in accordance with the requirements of the application at hand; it is possible to extend the focal range by up to 75 per cent over that of the unstopped beam while substantially maintaining the same focussed spot size.

Accordingly the invention provides a focussed laser beam optical system characterised by a substantial depth of focus and comprising the operative combination of a laser light source for generating a beam of coherent light having a predetermined cross-sectional shape and area and having a gaussian intensity distribution, an optical beam expanding lens system traversed by the beam for expanding the cross-sectional area of the beam, and an optical stop for reducing the cross-sectional area of the emergent beam.

In order that full advantage of the invention be obtained in practice, the best mode embodiment thereof, given by way of example only, is described in detail hereinafter with reference to the accompanying drawing, in which:

FIG. 1 is a schematic diagram of a prior art focussed laser beam optical system;

FIG 2 is a schematic diagram of a focussed laser beam optical system according to the invention; and

FIGS. 3 and 4 are graphical representations of the operation of an optical system according to the invention.

Description

A conventional focussed laser beam optical system is shown in FIG. 1. A laser beam 10, emanating from a laser 12, is arranged to pass a focussing lens system schematically represented here as a single lens 14 for bringing the beam to a focus at a desired target in a given plane represented here by a line 16. The laser beam 10 has a gaussian profile diametrically as represented here by a curve 18 superimposed on the diagram. A range of focus of the system as described is represented by the dimension 19.

In accordance with the invention, the range of focus of the system as shown and described, is increased by interposing an optical stop between the laser 12 and the focussing lens system 14. It should be clearly understood that the focussing lens system 14 and the optical stop 20 are located as shown, or the stop 20 and the lens system 14 may be exchanged. Also the optical stop 20 alternatively is located between component lenses of a plural element focussing lens system. The stop has an aperture related to the diameter of the beam 10 and the profile represented by the curve 18. The relationship will be discussed in greater detail hereinafter. While the basic arrangement is so readily described, it will more readily be understood with reference to FIG. 2. Here an optical stop 20 is shown in place not only with respect to the focussing lens system 14, but also with respect to an optical beam expanding system 22 which is interposed between the laser 12 and the optical stop 20. Laser sources are usually available in only a few standard beam diameters which are frequently not optimum for the application at hand. The use of an optical beam expanding system as disclosed herein is therefore helpful for most applications. The expanded laser beam 10' has a gaussian profile characteristic represented by a curve 28 and the optical stop 20 is chosen in accordance with this characteristic curve 28 as will be discussed hereinafter.

A suitable beam expander is that commercially obtainable from Spectra-Physics identified as their Model 338 Beam Expanding Telescope although any suitable expander can be used.

The principal object is to maintain the laser spot size at or near the desired target substantially constant over the entire scan field. As mentioned hereinbefore, it was found empirically, that truncating a laser beam resulted in a desirable increase in the focal range. Investigation with the aid of a computer verified the result, and a computer program was developed for optimizing the arrangement according to the invention.

An article entitled "Measurement and Analysis of the Distribution of Energy in Optical Images" published in the Journal of the Optical Society of America, Vol. 48, No. 7, pages 487-490, July 1958 discusses so-called "line spread functions". A line spread function may be defined as the two dimensional energy distribution in the focussed spot integrated in one direction. It is therefore the curve of the transmitted energy against distance which is obtained when the focussed spot is scanned over i.e. across a narrow slit situated normally to the direction of motion of the spot. Data was obtained on the line spread function width as a function of the degree of defocussing by means of a computer. These data were used to plot the curves of line spread function width at the 1/2 intensity and the $1/e^2$ intensity levels. For each degree of truncation, the calculation was made for an adjusted beam aperture size that produces the same in-focus line spread function 1/2 peak width, as would be obtained with the in-focus untruncated beam.

FIG. 3 is a graphical representation of a line spread function width at 1/2 peak points as a function of the distance from an ideal focus point for a range of defocussing. That is to say, FIG. 3 is a plot of the width of the line spread function at a point where the intensity is one half that of the peak intensity, and is plotted against the degree of defocusing. It is to be noted that the width of the line spread function grows as the lens is defocused. Note also, that for moderate amounts of defocusing (up to the point where the line spread function has grown to about 1.8 times the spread for the in-focus condition), that the spread functions associated with the truncated beams do not grow in width nearly as rapidly as the untruncated beams (represented by the $1/e^8$ curve).

Curves 31, 32, 33 and 34 respectively represent the truncation of the beam at the radius where the beam intensity is $1/e^8$, 0.08, $1/e^2$, and 0.2 of the peak intensity. The curve 31 for truncation at $1/e^8$ is essentially identical to that for the untruncated beam. The abscissa of this plot is also the number of wavelengths of defocussing of the untruncated beam, measured at the $1/e^2$ intensity points in the exit pupil of the focussing lens.

FIG. 4 is a graphical representation of the line spread function widths measured at the $1/e^2$ (or 13.5% of peak) intensity points, as a function of distance from ideal focus. Thus, FIG. 4 is the same as FIG. 3 except that the width of the line spread function at the point where the intensity is $1/e^2$ (13.5%) that of the peak is plotted against the degree of defocusing. Curves 41, 42, 43 and 44 correspond to the levels as listed above.

As can be seen from FIGS. 3 and 4, a considerable improvement in focal range is obtained by truncating the beam if the allowable spot size tolerance in the scanner or optical system is between zero and thirty or forty per cent of the spot size. The Applicants appreciated that there was a slower growth rate of the width of the line spread function when a beam having a Gaussian intensity distribution is expanded and thereafter truncated at the focussing lens than with a beam initially of the truncated section. This slower growth rate leads to the considerable and unexpected improvement in the focal range. In one printer where the spot size tolerance is 10 per cent of the spot size, the focal range is increased by about 50 per cent by truncating the beam at the radius where the intensity is 0.2 of that of the peak intensity. With a system in which the alignment and focussing of the system is difficult because of the limited focal range, this increase in focal range results in considerably reduced time required to align and focus the system.

While decreasing the optical stop diameter in the conventional camera lens also will act to increase the focal range, the arrangement according to the invention will do so without substantially changing the spot sizes whereas the spot will bloom in the former arrangement.

CLAIMS

1. A focussed laser beam optical system characterised by a substantial depth of focus and comprising the operative combination of a laser light source for generating a beam of coherent light having a predetermined cross-sectional shape and area and having a gaussian intensity distribution, an optical beam expanding lens system traversed by the beam for expanding the cross-sectional area of the beam, and an optical stop for reducing the cross-sectional area of the emergent beam.

2. A system as claimed in claim 1, in which the optical stop has an aperture of substantially the same predetermined cross-sectional shape and area as the unexpanded beam.

3. A system as claimed in claim 1, in which the optical stop has an aperture of substantially smaller cross-sectional area than the unexpanded beam.

4. A system as claimed in claim 1, 2 or 3, in which the unexpanded beam is of circular cross-section.

5. A system as claimed in claim 4, in which the optical stop is arranged to cut-off light in the beam having an intensity less than 20% of the peak intensity.

6. A system as claimed in claim 5, in which the optical stop is arranged to cut-off light in the beam having an intensity less than 8% of the peak intensity.

7. A focussed laser beam optical system providing increased focal range, comprising a laser for generating a beam of coherent light having a given diameter and a guassian profile diametrically, an optical beam expanding lens system aligned with said laser and an optical stop

aligned with said lens system and having an aperture of substantially said given diameter of said beam of light whereby the focal range is substantially greater than for the original focussed beam.

8. A focussed laser beam optical system as claimed in claim 7, modified in that said aperture has a diameter substantially less than the diameter of said beam.

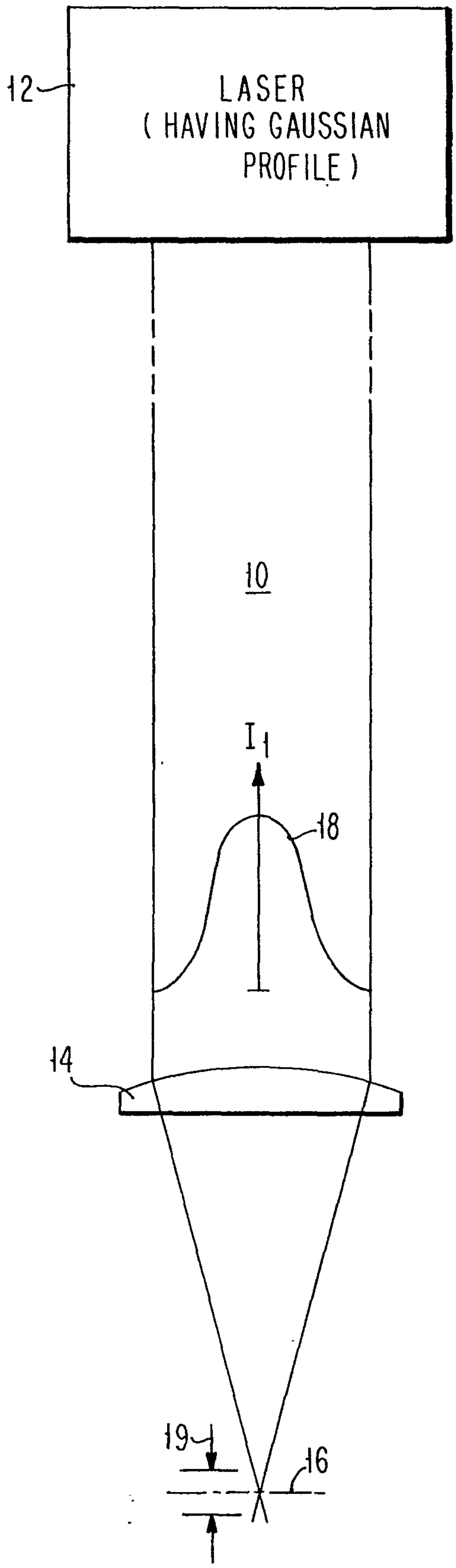

12
LASER
(HAVING GAUSSIAN
PROFILE)
10
I1
18
14
19
16

FIG. 1

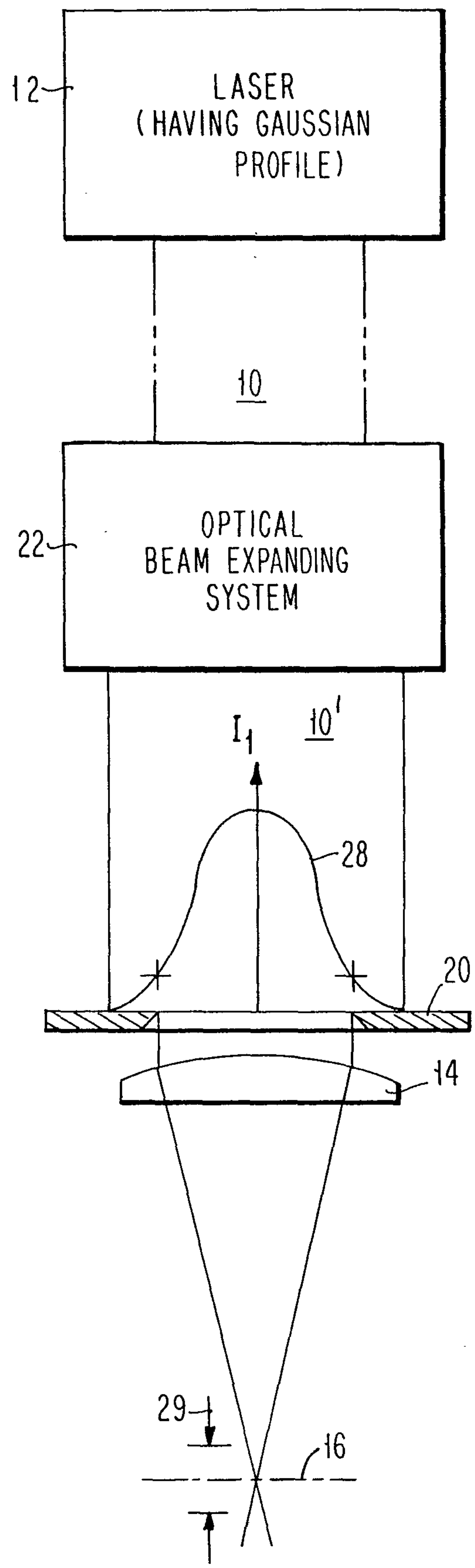
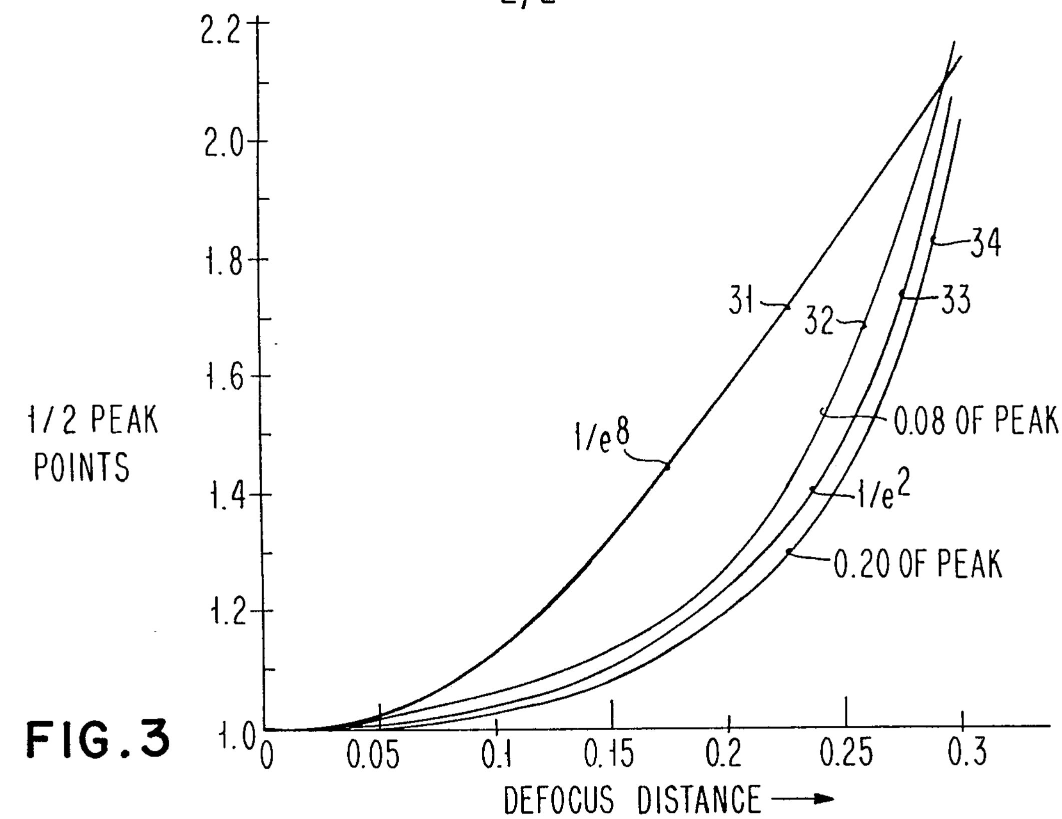
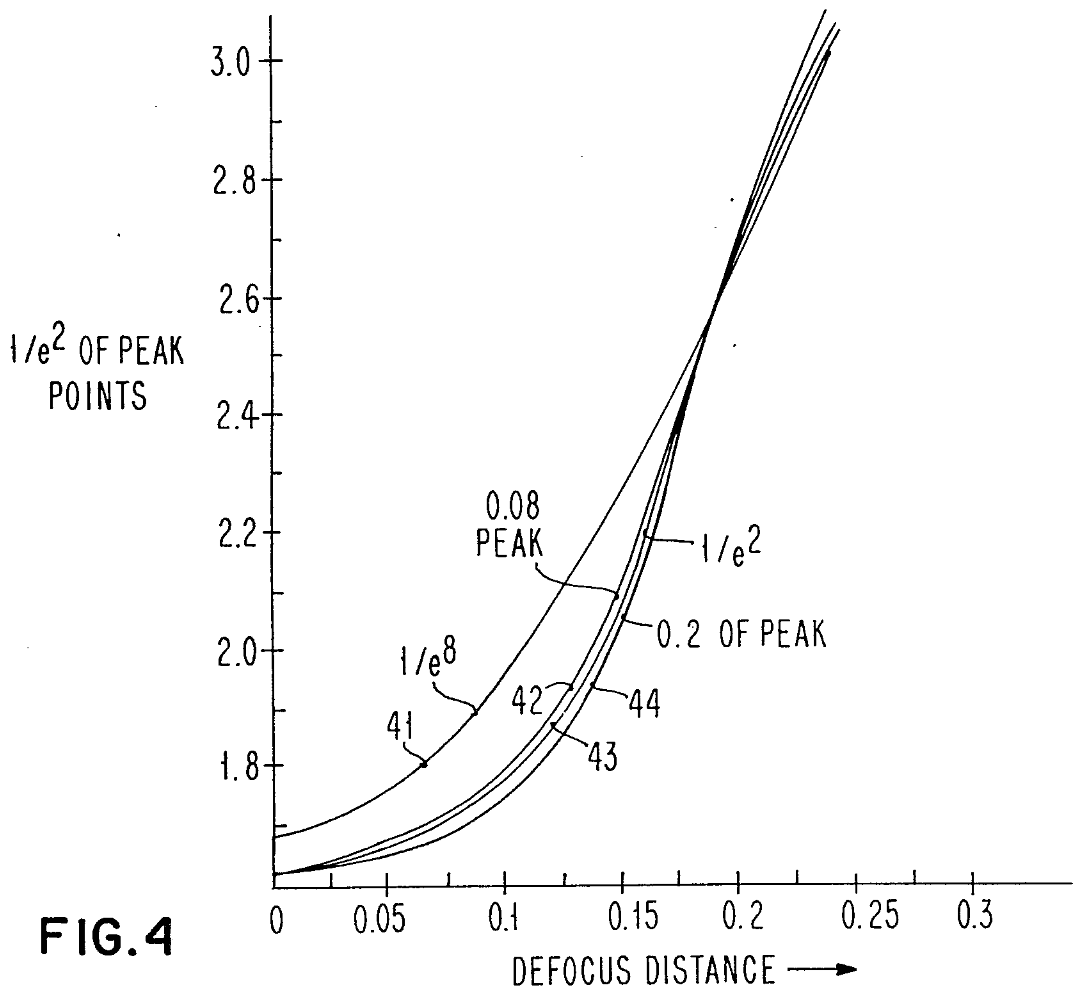

12
LASER
(HAVING GAUSSIAN
PROFILE)
10
22
OPTICAL
BEAM EXPANDING
SYSTEM
I1
10'
28
20
14
29
16

FIG. 2



2.2
2.0
1.8
1.6
1.4
1.2
1.0
1/2 PEAK POINTS
0
0.05
0.1
0.15
0.2
0.25
0.3
DEFOCUS DISTANCE
1/e8
31
32
34
33
0.08 OF PEAK
1/e2
0.20 OF PEAK

FIG.3



3.0
2.8
2.6
2.4
2.2
2.0
1.8
1/e2 OF PEAK POINTS
0
0.05
0.1
0.15
0.2
0.25
0.3
DEFOCUS DISTANCE
0.08 PEAK
1/e2
0.2 OF PEAK
1/e8
41
42
44
43

FIG.4

European Patent Office

EUROPEAN SEARCH REPORT

0019778

Application number
EP 80 10 2562

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	US - A - 3 787 107 (SICK) * Figures 1 and 2; "Abstract", column 4, line 10 to column 5, line 54 * --	1	G 06 K 7/10 H 01 S 3/00 G 02 B 5/00
A	US - A - 3 750 189 (FLEISCHER) * Figures 1 to 4; column 2, line 56 to column 3, line 11 * --	1	
A	FR - A - 2 040 507 (COMMISSARIAT A L'ENERGIE ATOMIQUE) * The whole document * --	1	TECHNICAL FIELDS SEARCHED (Int.Cl. 3) G 06 K 1/12 7/10 15/12 15/14 G 02 B 5/00 27/00 G 11 B 7/12 H 01 S 3/00 B 23 K 26/06
A	US - A - 3 980 397 (O'DEAN) * Figures 1 and 2; column 1 * --	1	
A	REVIEW OF SCIENTIFIC INSTRUMENTS, vol. 45, nr. 11, November 1974 NEW YORK (US) B.J. PERNICK: "Irradiance uniformity and power loss with a spatially filtered laser beam", pages 1344 to 1346 ----	1	

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	26.08.1980	PESCHEL